Jet production in diffractive processes at HERA

HEP2005 International Europhysics Conference on High Energy Physics
21-27 Jul 2005
Lisboa, Portugal

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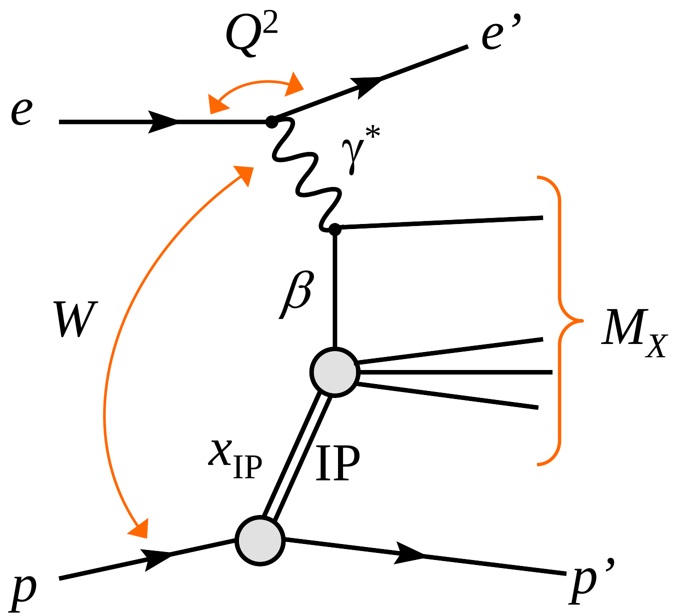
Kinematics in diffraction

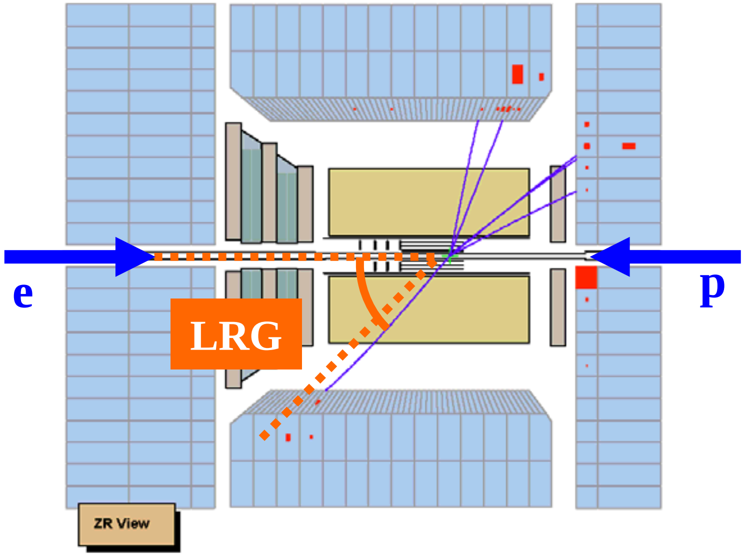


- Q^2 : negative squared mass of photon
- W : virtual photon-proton CMS energy
- M_X : mass of hadronic system X
- x_{IP} : proton momentum fraction of the colorless exchange: Pomeron (IP)
- β : longitudinal momentum fraction of the exchange carried by the struck quark

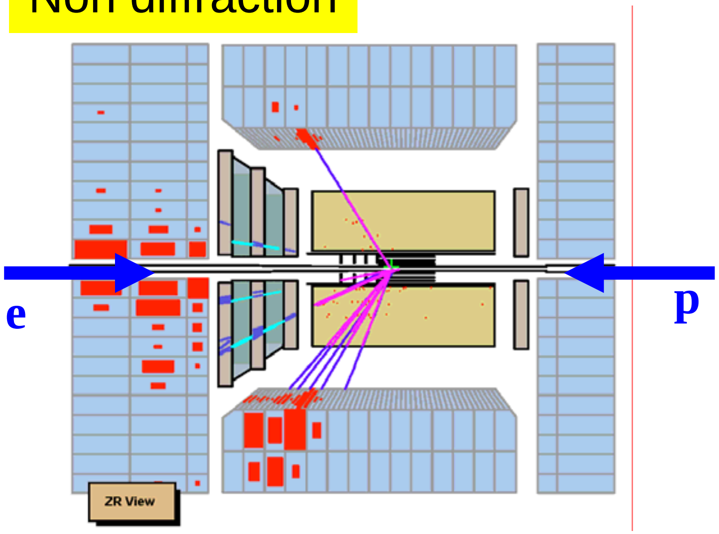
Event topology in diffraction at HERA

- Diffractive exchange: exchanging states with vacuum quantum number
  - Colorless exchange
  - Producing large rapidity gap (LRG)

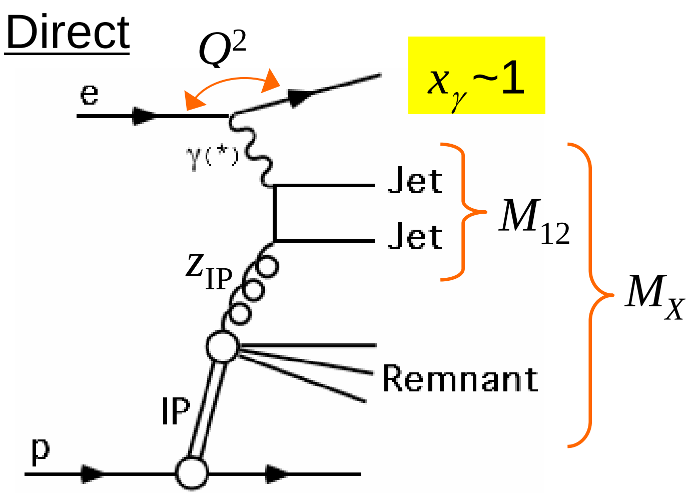
Diffractive scattering

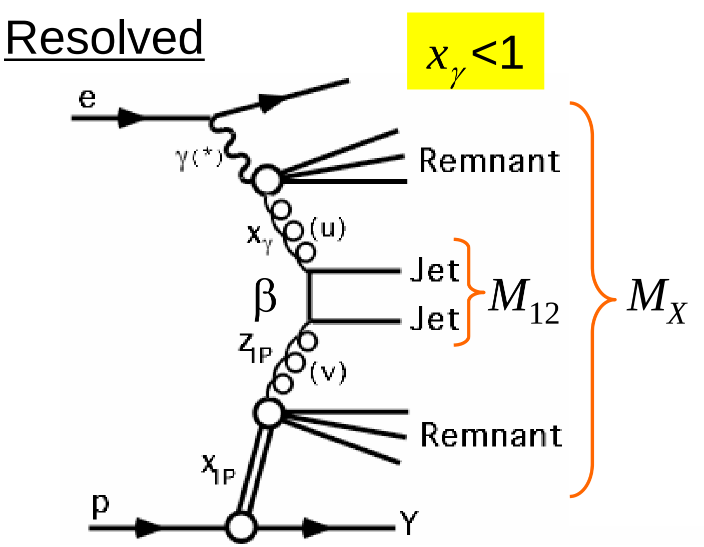


Non diffraction



Kinematics in diffractive dijet





Dijet events can reconstruct the parton momentum from jets

$$z_{IP}^{jets} = z_{IP}^{obs} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$$

$\mathbf{z_{IP}}$ **:** Longitudinal momentum fraction of the parton for **Pomeron** related to the exchange for the hard interaction

$$x_\gamma^{jets} = x_\gamma^{obs} = \frac{\sum_{jets} E - p_z}{\sum_{hadrons} E - p_z}$$

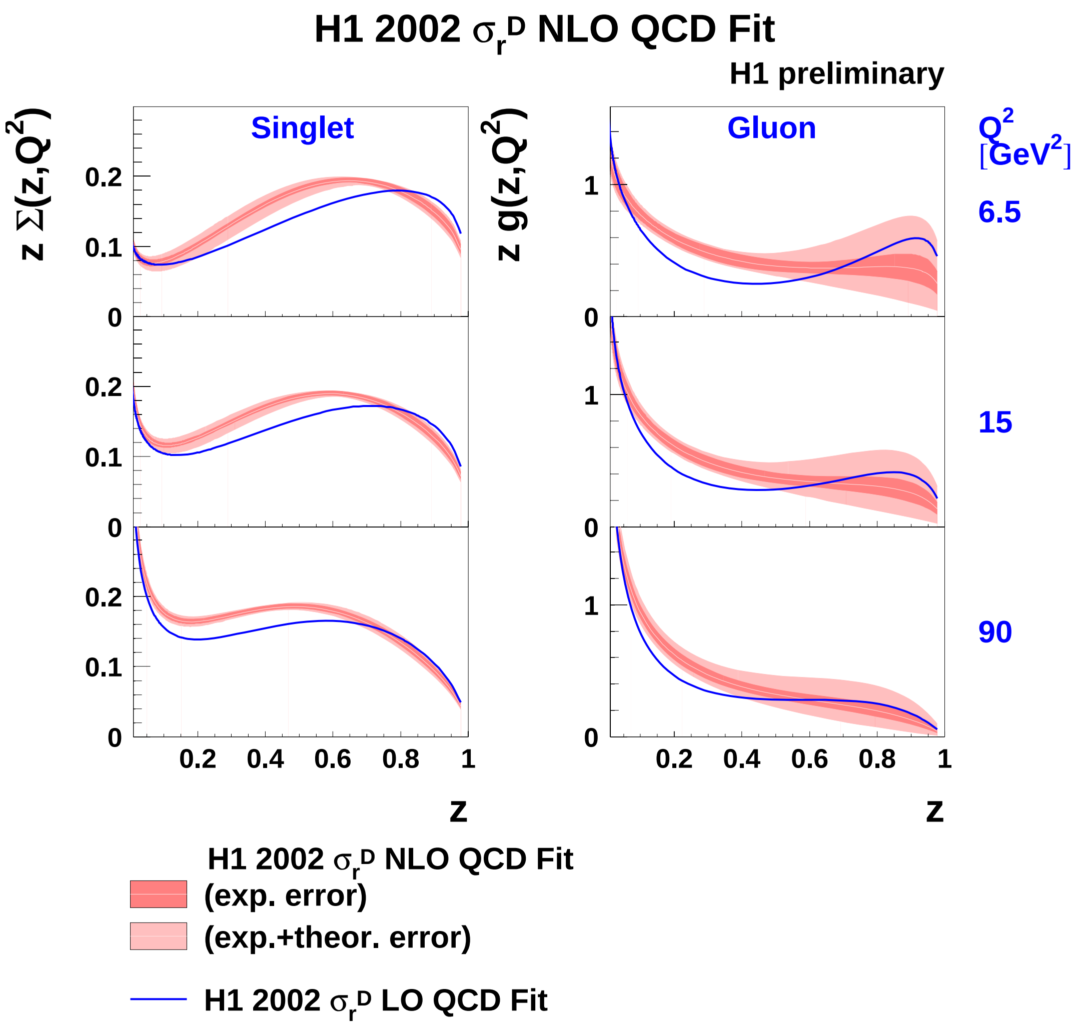
$\mathbf{x_\gamma}$ **:** Longitudinal momentum fraction of the parton for **photon** related to the exchange for the hard interaction

What is DIS or Photoproduction (PHP) ?

- DIS: $Q^2 >> 0$, mostly Direct
- PHP: $Q^2 \sim 0$, Direct + Resolved

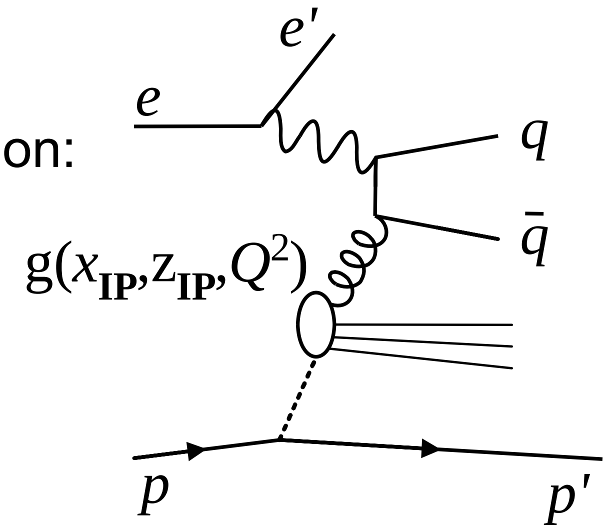
Diffractive Parton Density Function (DPDF)

- Diffractive PDF:
  - like the normal PDF, but under the condition that a diffractive exchange is involved.
  - Reasonable description of inclusive diffractive measurements (See talk given by L.Schoeffel)
- **Gluons** from scaling violation
  - **Large uncertainties**
- Example: H1 2002 fit:
  - Gluon density is larger than quarks (~75 %)
  - Gluon uncertainties is large at high z.
    ➔ Need to constrain the gluon with the other process



Diffractive PDFs and factorization

- Hard scattering for non-diffractive process:
  QCD factorization holds for jet production



- Assuming that this can be applied also in diffraction:
  - Cross section: convolution of matrix element and **diffractive parton density**

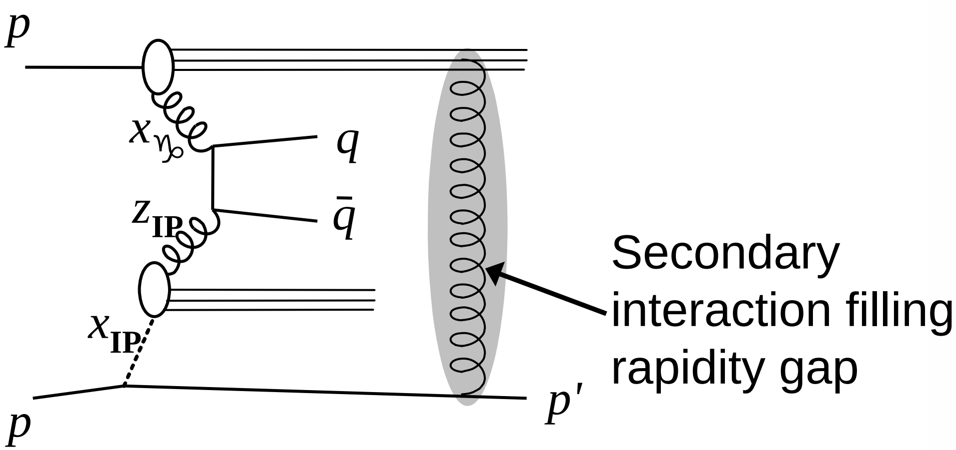
$$\sigma_{\text{dijets}}(\gamma^* p \to Xp) = \sum_{i=q,g} \sigma_{\gamma i \to jj} \otimes f_i(z_{\text{IP}})$$

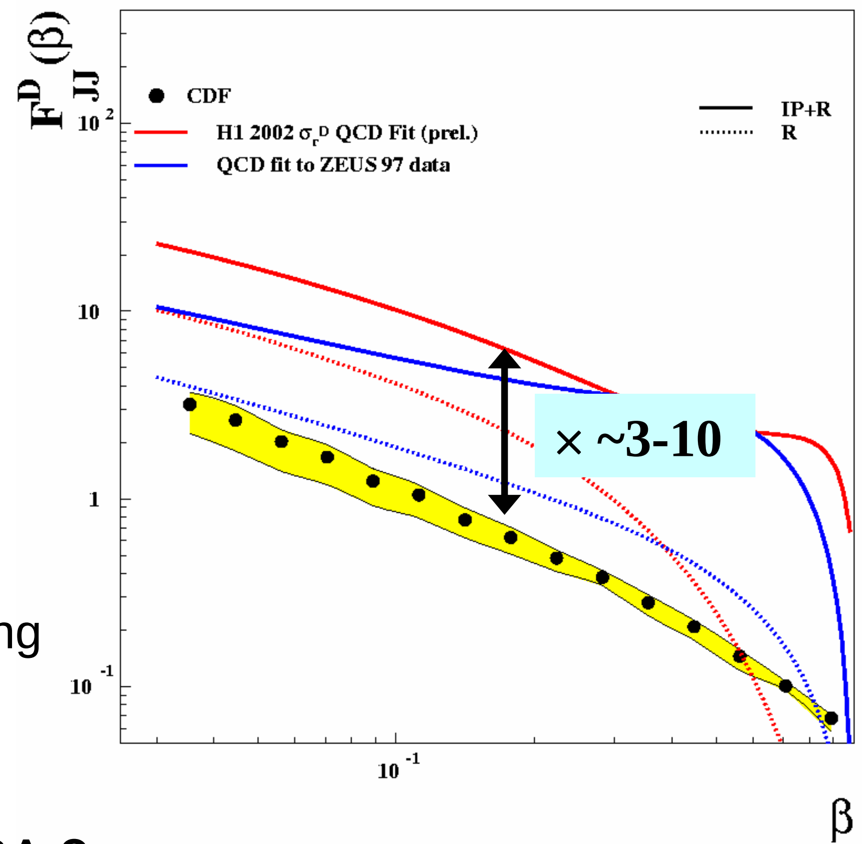
- Diffractive dijet events can reconstruct z_{IP}
  - z_{IP} : Longitudinal momentum of the parton to hard scattering

- Dijet process: mainly from BGF (Boson-gluon-fusion) diagram
  ➔ **Dijet is sensitive to diffractive gluon density**

Factorization breaking between *ep* and *pp* ?

- CDF result in *pp* collisions at Tevatron is factor ~3-10 lower than QCD fit using HERA diffractive PDFs.
- Why DPDFs from HERA do not work ?





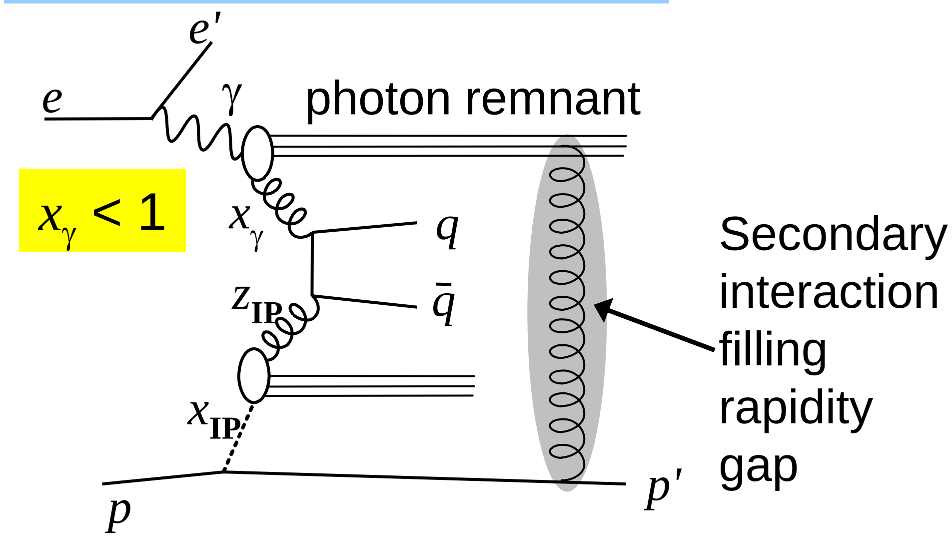
- **Suppression in diffractive dijet at HERA ?**

➔ Theoretically expected, explanation next

Jets in Photoproduction (PHP) at HERA

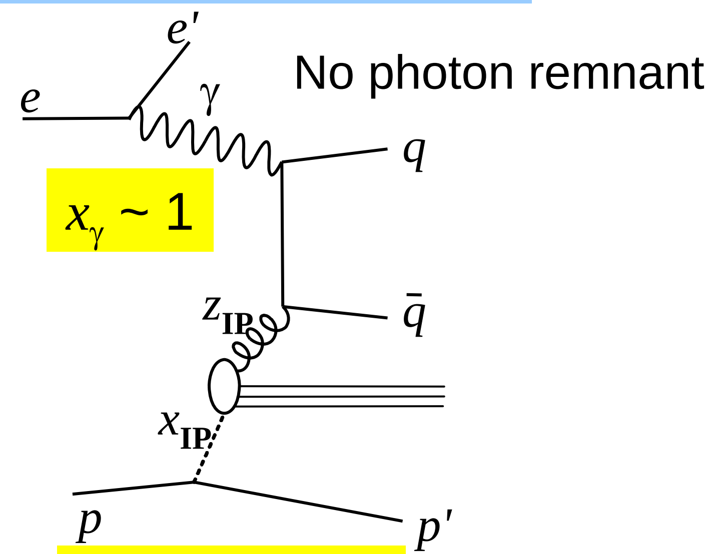
- Jets in Photoproduction (PHP):
  thought to be an ideal testing ground for rescattering

Large (resolved) : hadron-like



Suppressed

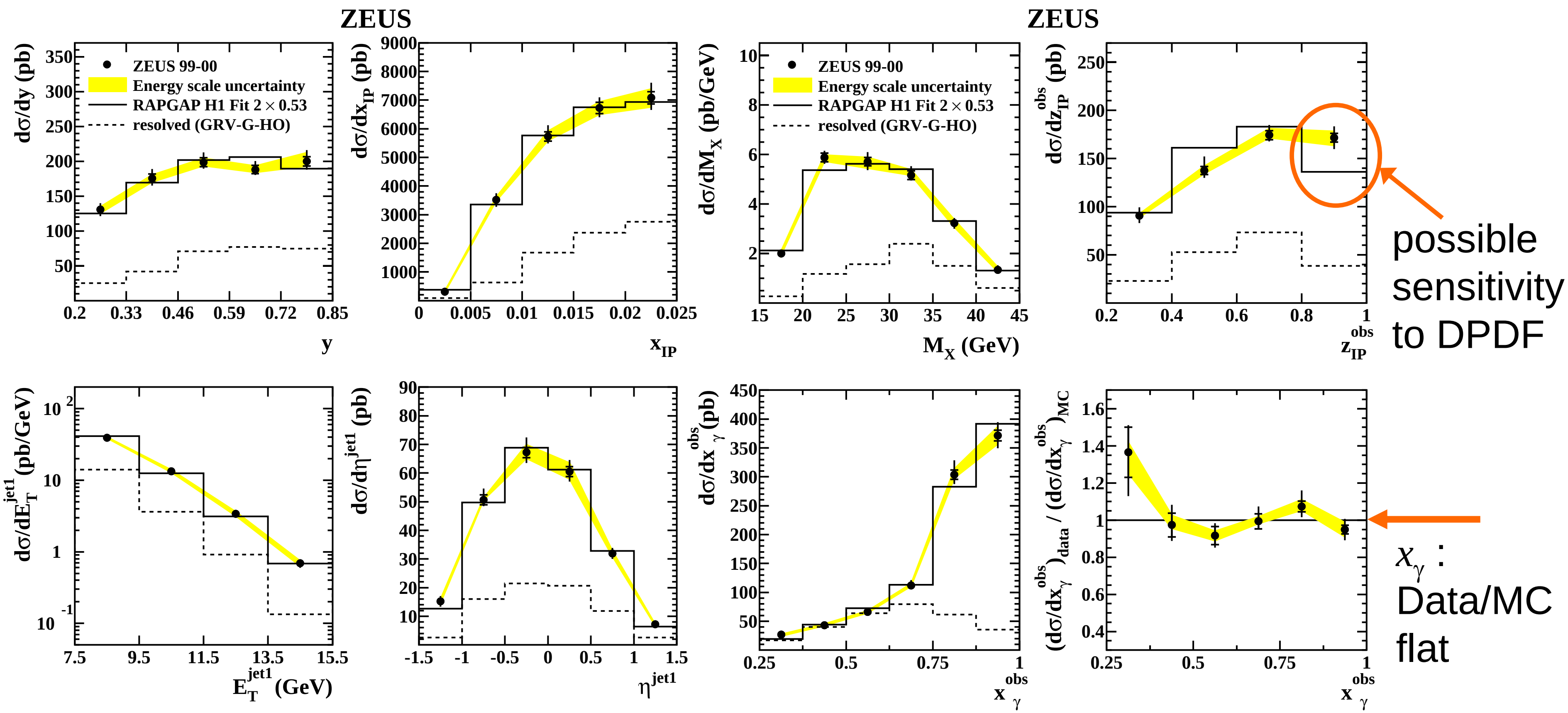
Small (direct) : point-like



Unsuppressed

- Dijet in PHP will be suppressed
- Prediction from Kaidalov et al.:
  Suppression factor for resolved photoproduction R=0.34
  ➔ PHP result on the next slide

Dijet in PHP: shape comparison with LO MC



- Shape of cross section is well described by MC normalised to data.
  - MC does not include suppression of the resolved PHP contribution.
- Data / MC is flat in x_γ: No sign of resolved suppression
  - Some excess at highest z_{IP}: sensitivity to diffractive PDFs

Suppression of PHP: Comparison with NLO

- NLO suppose to give stable prediction in normalisation
  - Comparison of absolute cross sections
  - Scale uncertainty in band

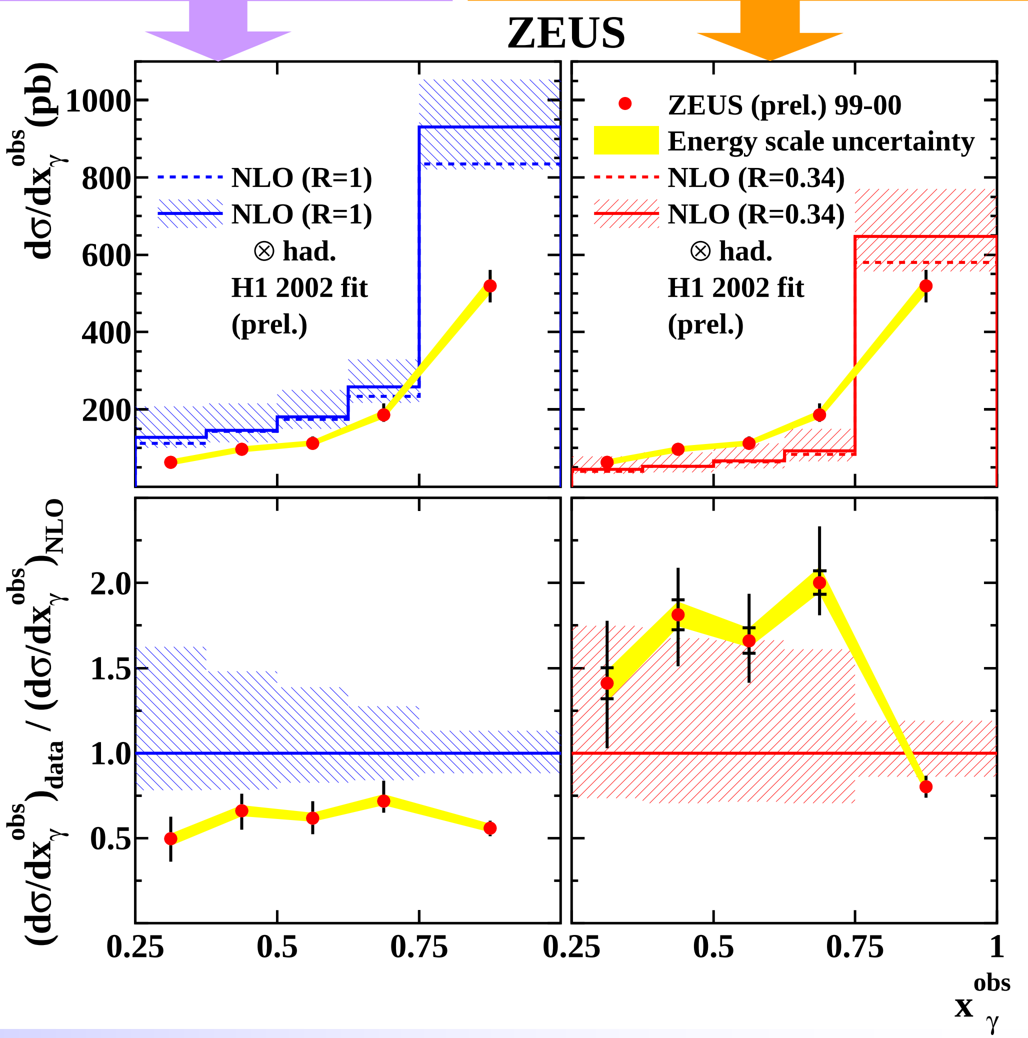
Result:

- Data/NLO(R=1) is flat in x_γ
  - Consistent with LO+PS
- But…
  Data is lower than NLO(R=1) by ~0.6
- NLO(R=0.34) describes data in shape and normalization.

➔ Suppression of both direct and resolved

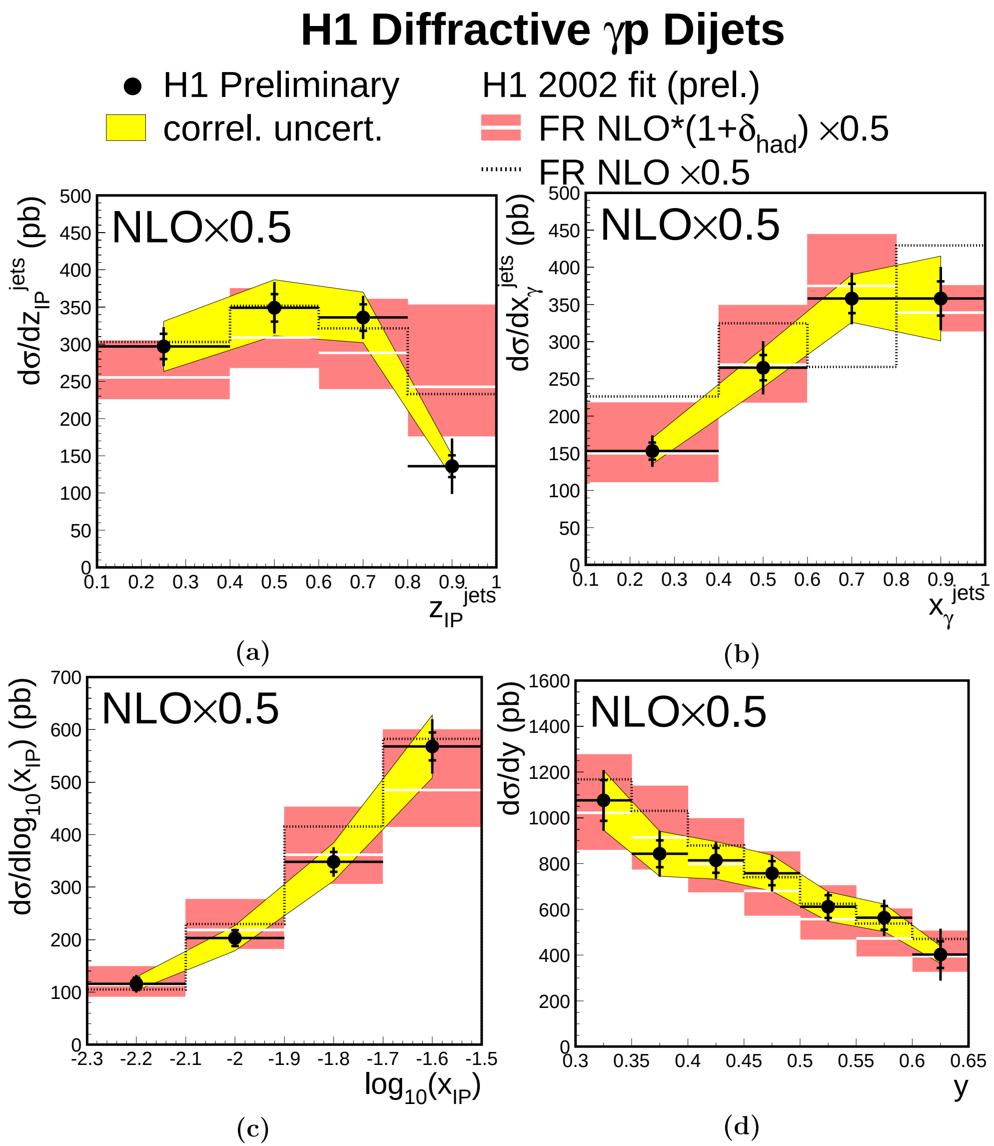
No resolved suppression by R=1

Prediction from Kaidalov et al.: Resolved suppression by R=0.34

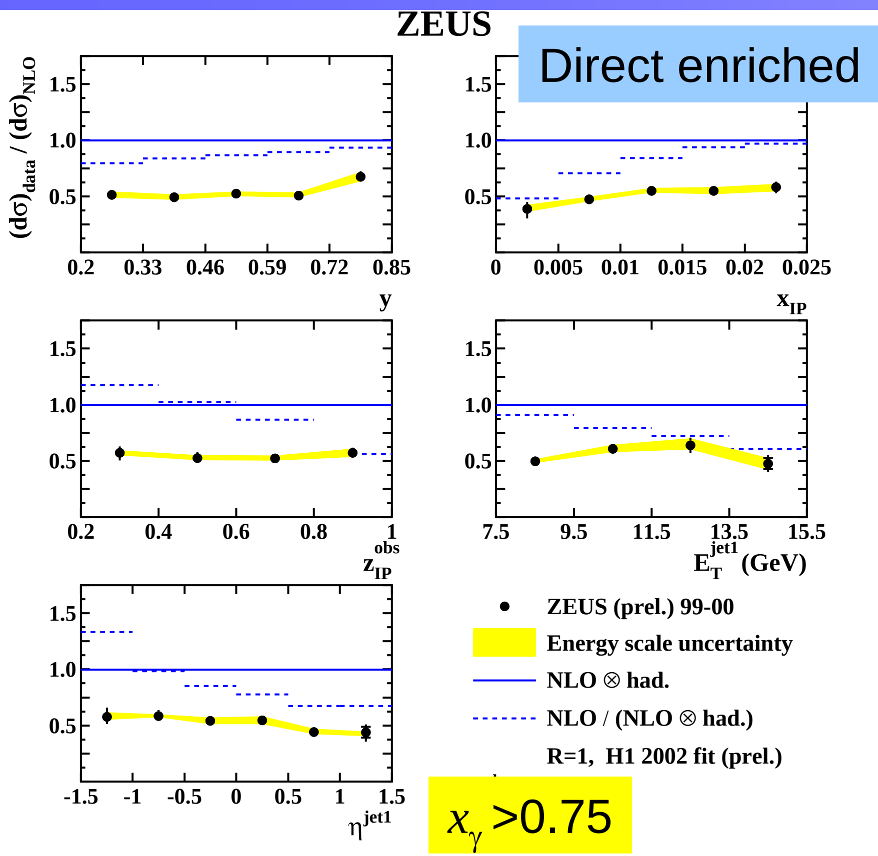


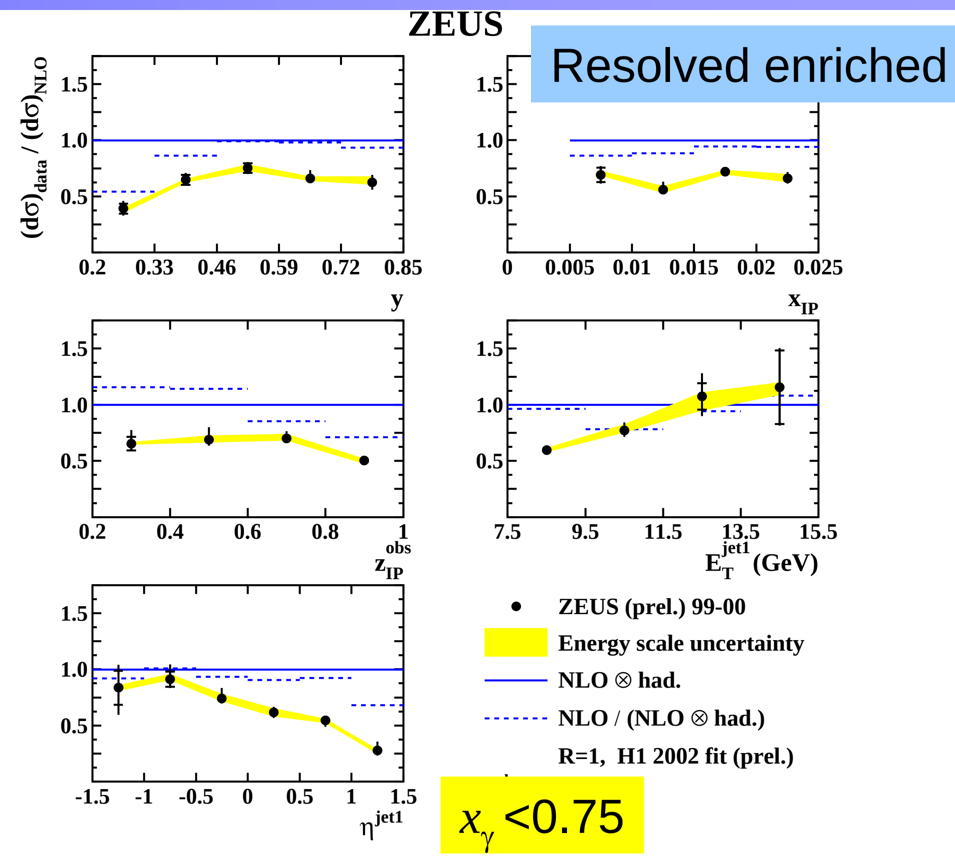
Suppression of PHP: Comparison with NLO

- Like seen in x_γ distribution
  - Normalization factor in PHP is ~0.5.
  - Shape of NLO in PHP describe data.
- Look more in detail…
  ➔ See next slide



Double differential cross sections for PHP





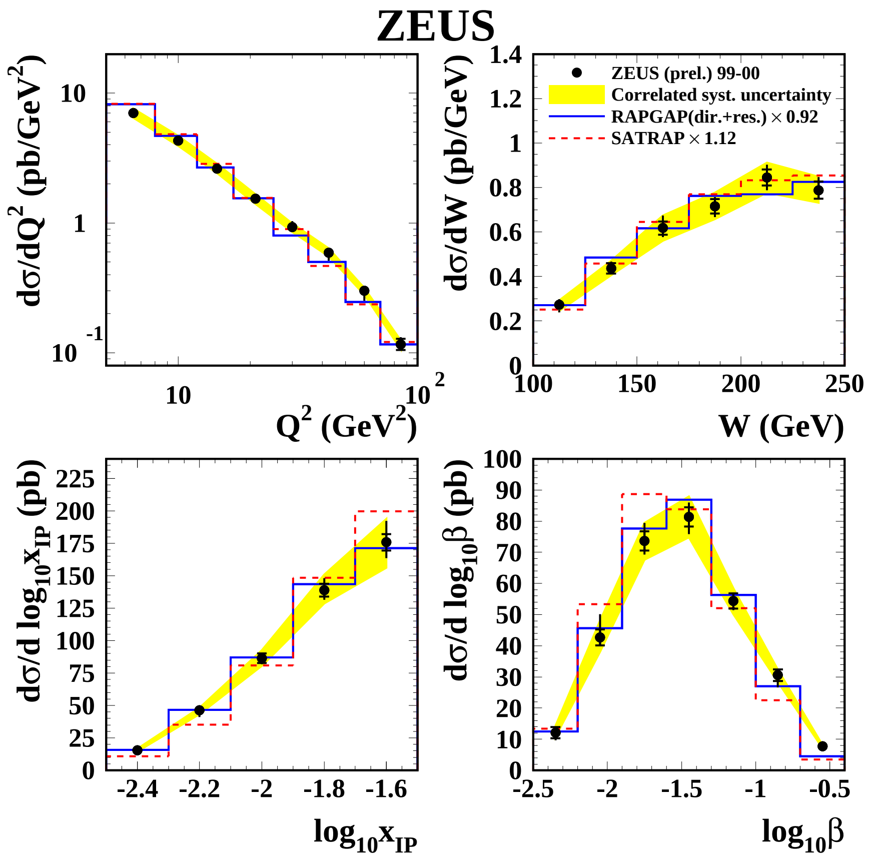
- Data / NLO is approximately flat.
- Data for both direct enriched and resolved enriched
  - Data for both x_γ>0.75(direct) and x_γ<0.75(resolved): suppressed by ~0.6
  - Both direct and resolved are well described in shape, but the magnitude of the cross sections is suppressed, assuming that H1 2002 fit is correct.

Dijet in DIS: Comparison with LO MC

- Is the factorization breaking in diffractive dijets ?

➔ Check DIS events
Presence of hard scale (Q^2) should suppress rescattering.

- Both H1 and ZEUS has measured dijet cross sections
  - ZEUS: Proton dissociation (16±4%) was subtracted.
  - H1: No subtraction of proton dissociation
- Comparison with LO MC:
Shape is well described by LO+PS MCs (RAPGAP, SATRAP) (normalized to data).



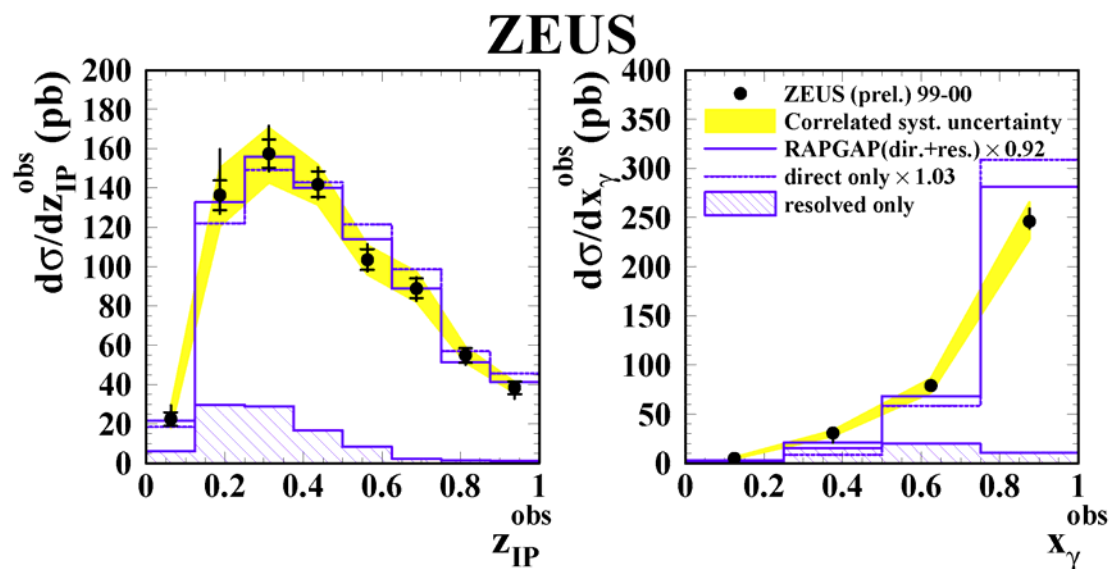
Kinematic range

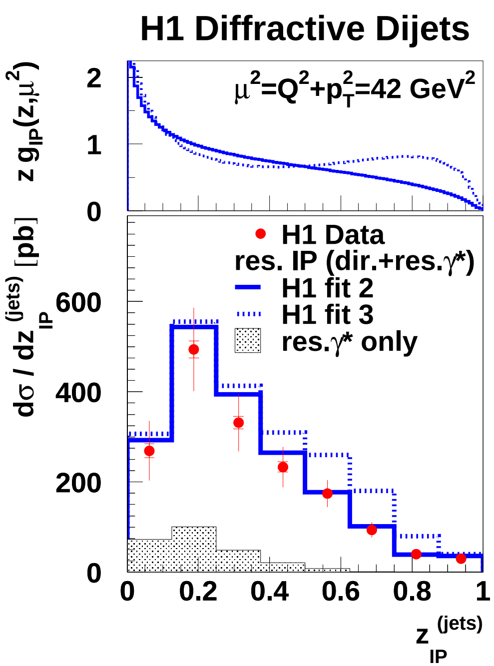
- $5 < Q2 < 100$ GeV², $100 < W < 250$ GeV
- $x_{IP} < 0.03$
- $N^*_{jet} \geq 2$, $E^*_{T,1jet} > 5$ GeV, $E^*_{T,2jet} > 4$ GeV
- $-3.5 < \eta^*_{jet} < 0$

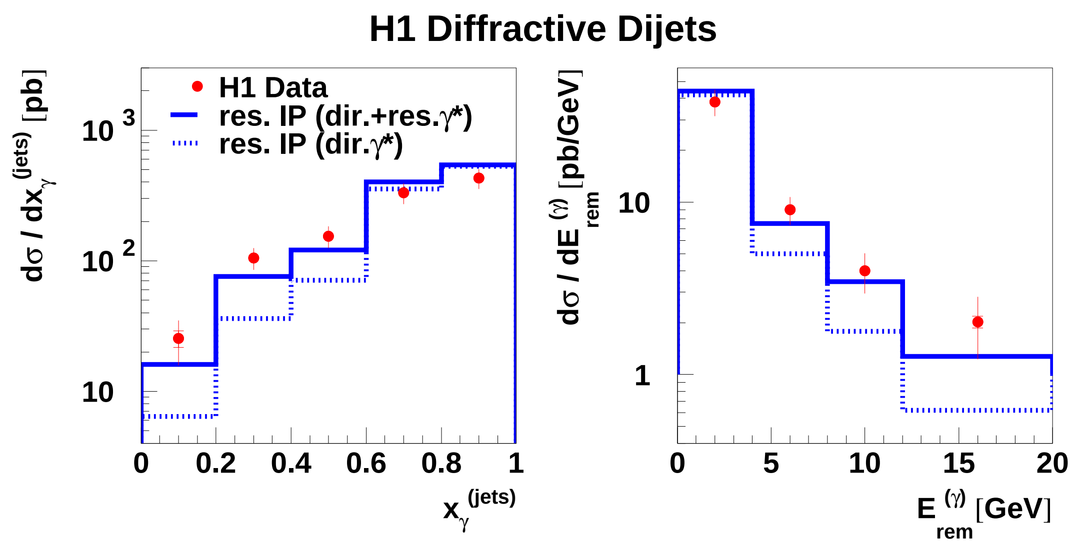
Dijet in DIS: Comparison with LO MC

- LO MC (dir.+res.) describe shape of cross section well.
- LO MC (dir.only) does not describe shape of cross section for x_γ

➔ **Contribution of resolved process in diffractive DIS**



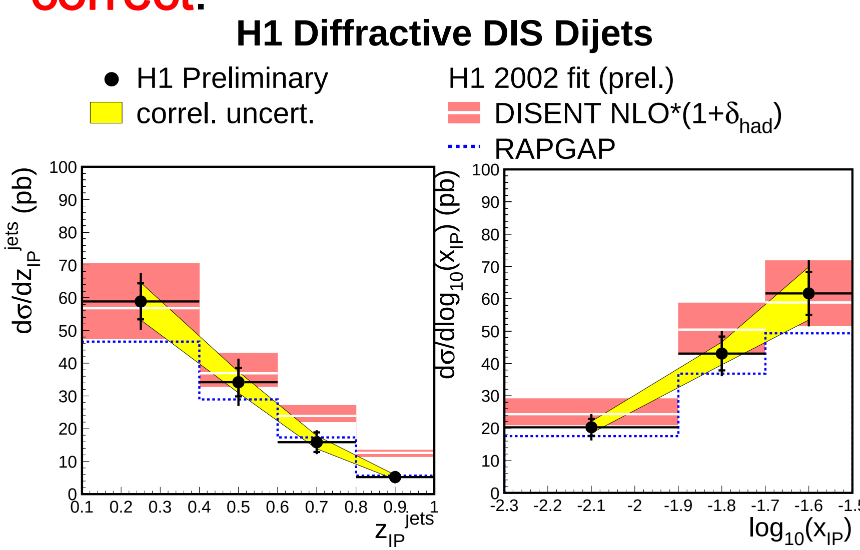




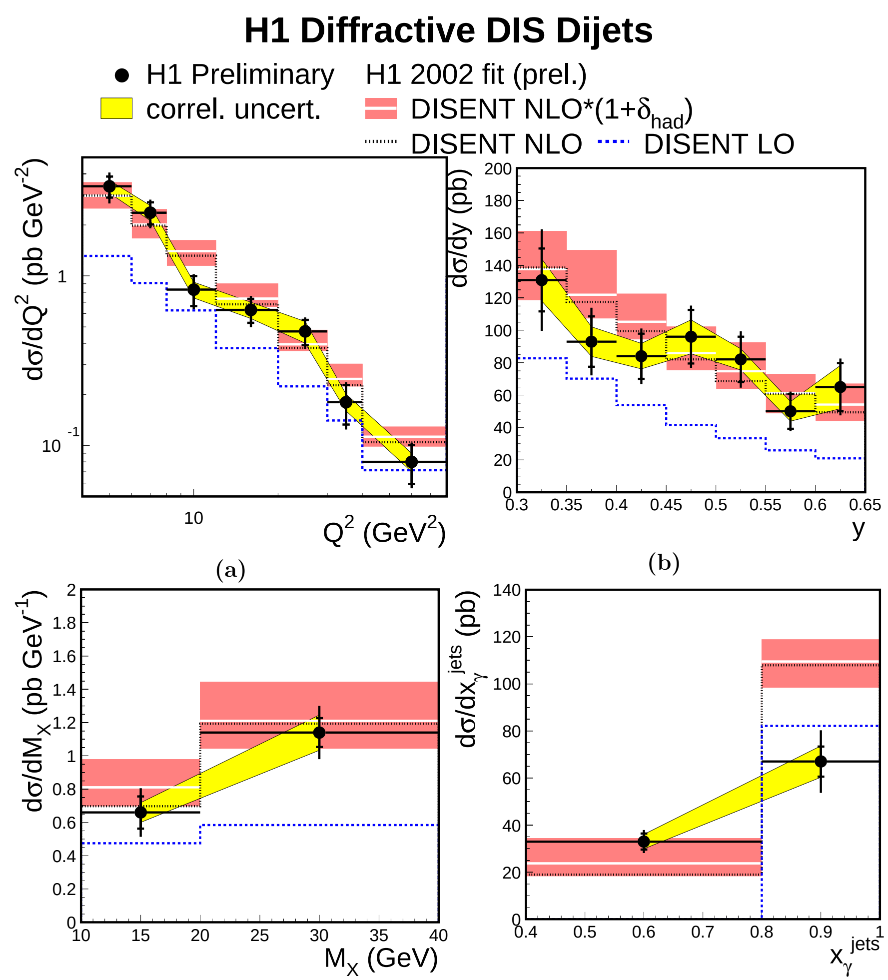
Dijet in DIS: Comparison with NLO prediction

- Kinematic range:
  - 165 < W < 242 GeV
  - $N_{jet}^{*} \geq 2$, $E_T^{*,jet1} > 5$ GeV, $E_T^{*,jet2} > 4$ GeV
  - DIS: $4 < Q^2 < 80$ GeV^2, $-3 < \eta_{jet}^{*} < 0$
  - $x_{IP} < 0.03$
- Good agreement with NLO using H1 2002 fit PDFs

➔ **Factorization holds in dijet events, assuming DPDFs (H1 2002 fit) is correct.**



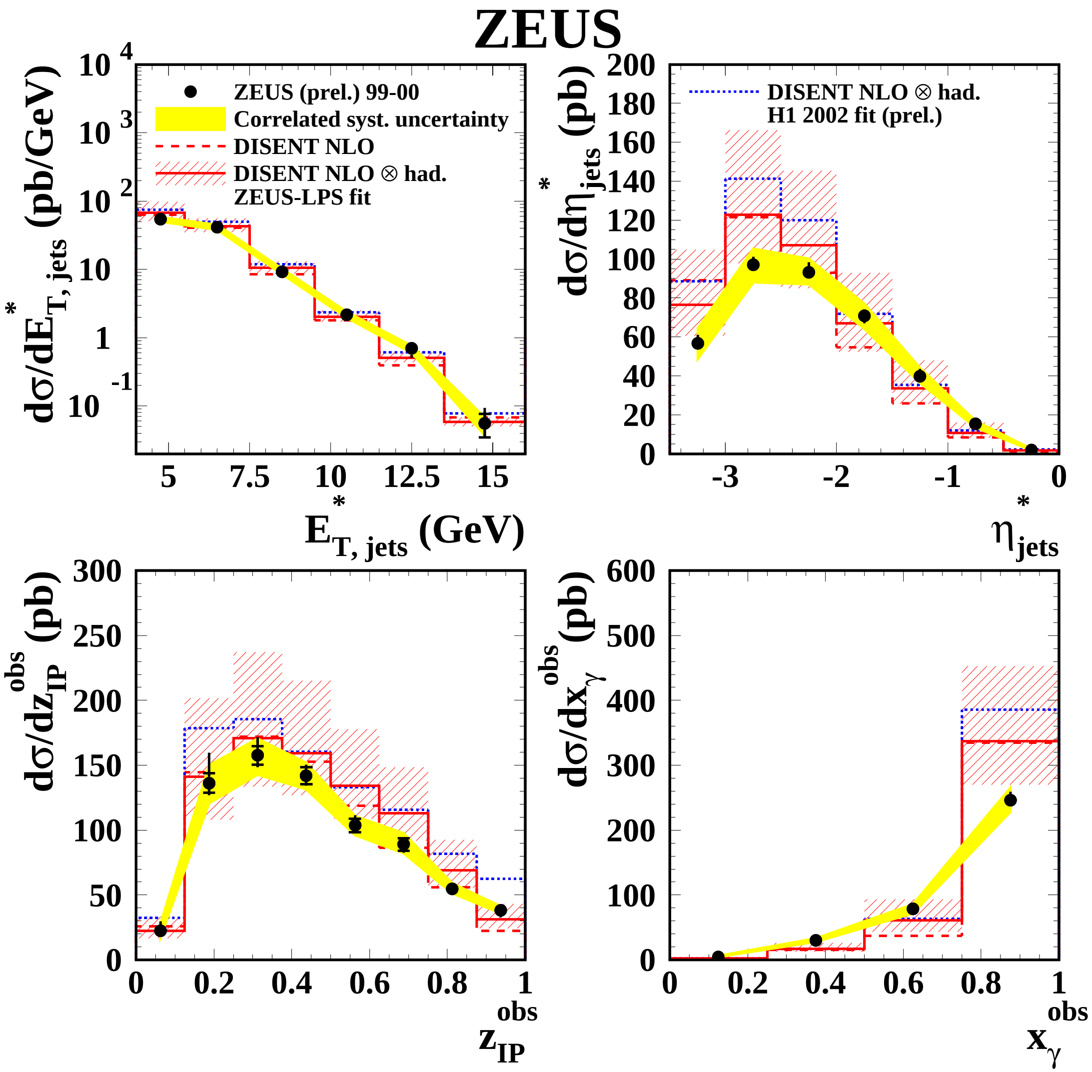
(a) (b)



(a) (b)

(c) (d)

Dijet in DIS: Comparison with NLO prediction

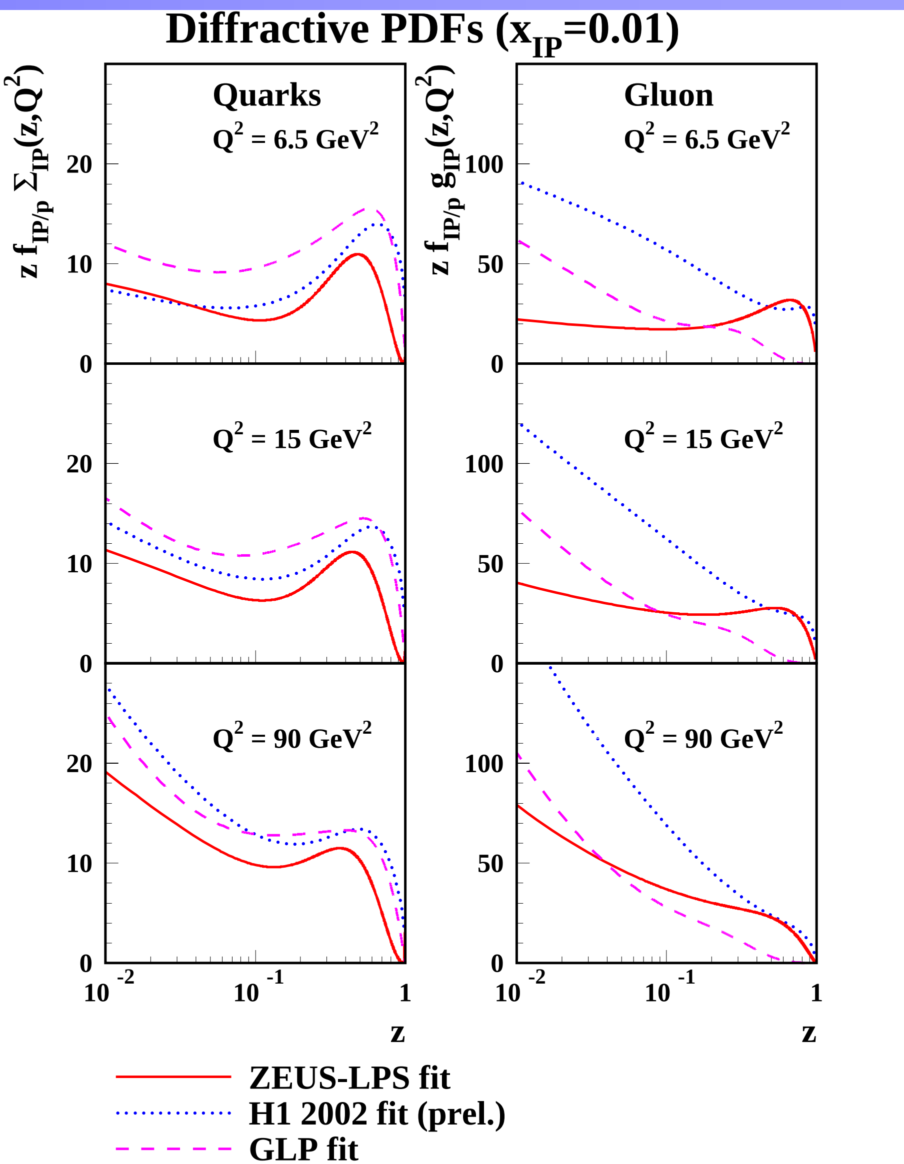


- Comparison of both NLO with H1 2002 fit and ZEUS-LPS fit DPDFs
- ZEUS-LPS fit: to F_2^D measured using ZEUS leading-proton spectrometer (LPS) and charm cross sections F_2^{charm}
- Scale uncertainty (band) by $0.5\ E^*_{T,jet1} < \mu_r < 2\ E^*_{T,jet1}$ → ~20% uncertainty
- NLO prediction with both DPDFs describe data in normalization ➔ **Factorization holds if we assume these DPDFs are correct.**

Uncertainty in diffractive PDFs

- New PDF fit recently available: GLP fit using the fit to the ZEUS F_2^D data (using M_X method): presented in HERA-LHC Workshop
- H1 2002 fit: to H1 F_2^D data
- ZEUS-LPS fit: to F_2^D by LPS and F_2^{charm}
- Quark density similar
- **Gluon density largely different at high** z (= Longitudinal momentum of parton)
- GLP fit for M_X data is below H1/LPS at high z

➔ Comparison of dijet cross section to NLO prediction using these fits

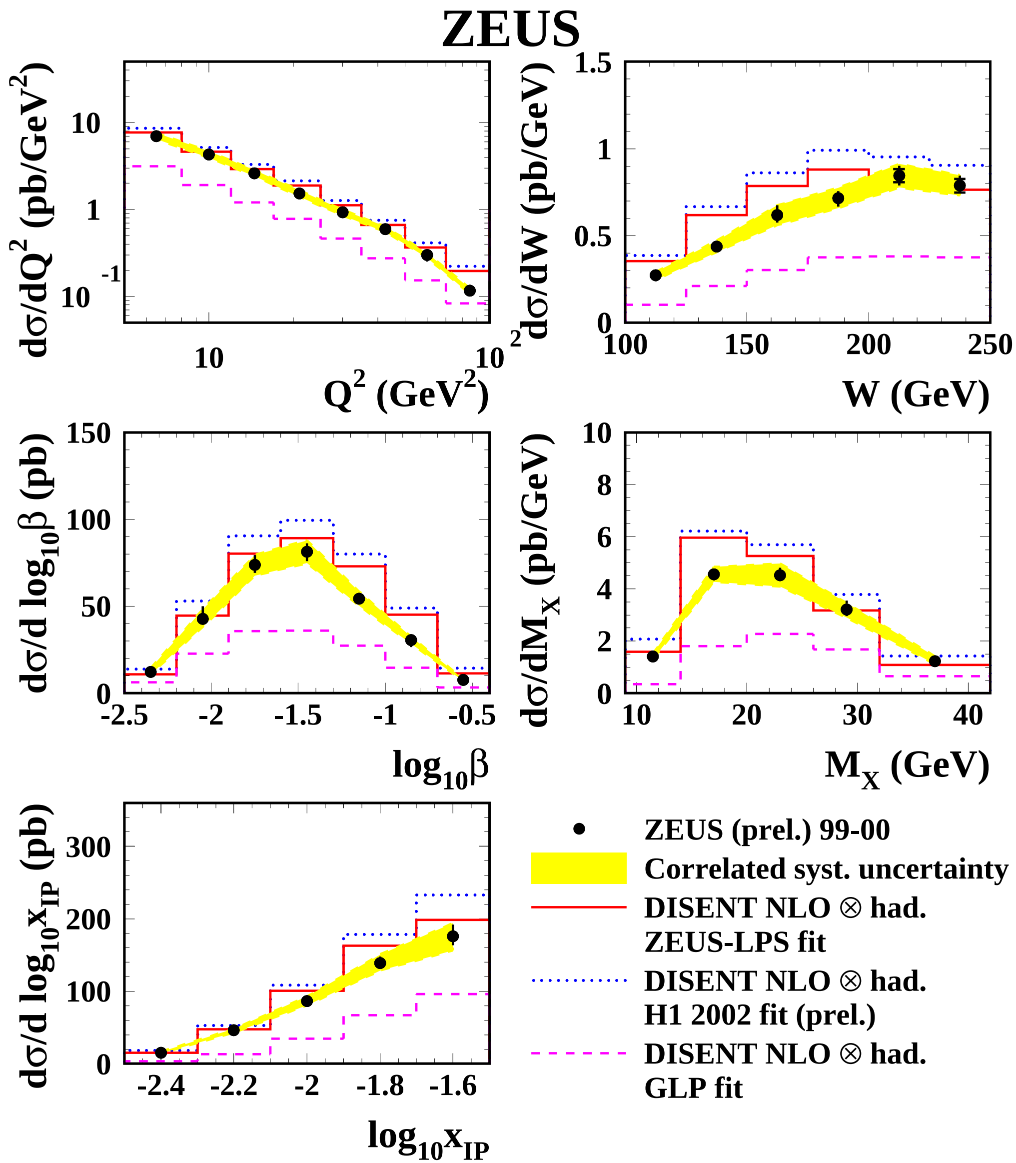


Comparison to NLO with various DPDFs (1)

- NLO prediction with ZEUS-LPS fit and H1 2002 fit DPDFs describe data in normalization.

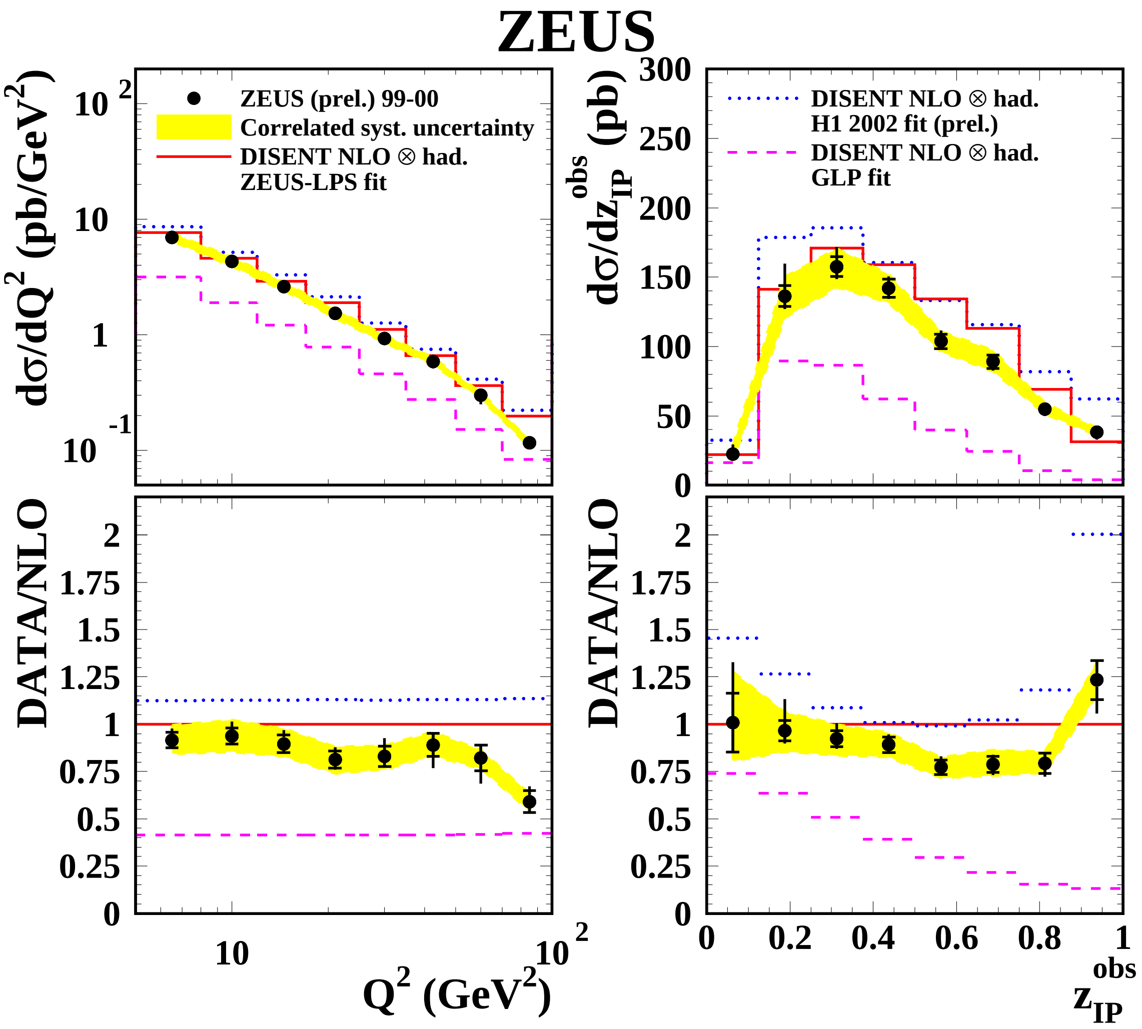
- NLO prediction with GLP is below data.

➔ DPDFs uncertainties
  - Poorly constrained gluon density



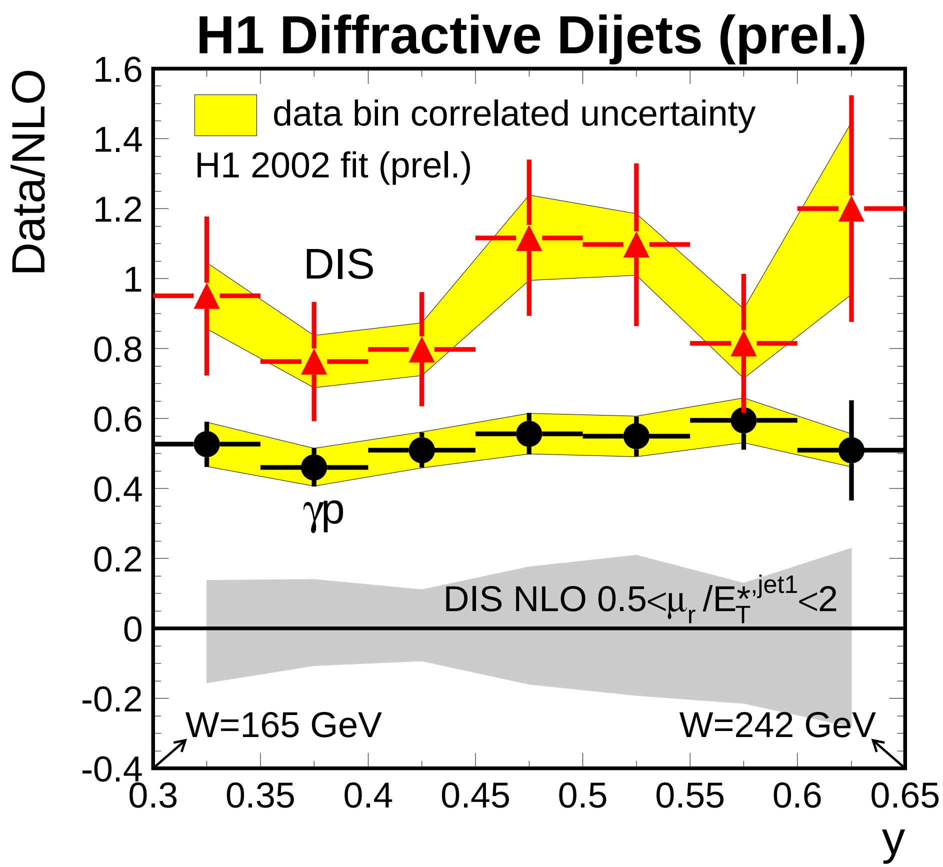
Comparison to NLO with various DPDFs (2)

- NLO prediction with GLP is below data.
  ➔ Difference in the shape and normalization on the diffractive gluon density.
- Difference between 3 sets of NLO prediction
  ➔ Uncertainty in DPDFs
- This data would help understanding the partonic structure of the diffractive exchange.



Ratio Data / NLO with DIS and PHP

- Kinematic range as common as possible:
  - $165 < W < 242$ GeV
  - $N_{jet}^{*} \geq 2$, $E_T^{*,jet1} > 5$ GeV, $E_T^{*,jet2} > 4$ GeV
  - DIS: $4 < Q^2 < 80$ GeV^2, $-3 < \eta_{jet}^{*} < 0$
  - PHP: $Q^2 < 0.01$ GeV^2, $-1 < \eta_{jet}^{lab} < 2$
  - $x_{IP} < 0.03$
- Cross sections are compared through the ratio to NLO using the same DPDFs (H1 2002 fit)
- Reducing the uncertainty in diffractive PDFs when comparing DIS and PHP cross sections. PHP cross section is suppressed by 0.5 w.r.t. DIS.



Conclusion

- Dijet cross sections are measured in both photoproduction and DIS.
- Cross sections are compared with NLO calculations with diffractive PDFs extracted from DGLAP QCD fit to HERA F_2^D measurements.
- Photoproduction cross sections are by 0.5-0.6 below NLO using DPDFs, which describe DIS data (H1 2002 fit).
  ➔ Factorization breaks in photoproduction if the assumed DPDFs are correct.
- NLO prediction with various DPDFs extracted from HERA F_2^D shows large variation in dijet cross section, reflecting large uncertainty in DPDFs.
- NLO prediction with one set of DPDFs cannot simultaneously describe photoproduction and DIS dijet data.
- Both photoproduction and DIS dijet give constraint on the model of the partonic structure of the diffractive exchange, e.g. DPDFs.